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Traumatic spinal cord injuries due to falls from trees in a tertiary rehabilitation center: a retrospective analysis of causes and outcomes

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ABSTRACT

Aims: Falls from heights are a major cause of spinal cord injury. In developing countries such as Turkiye, where fruit picking from trees is an important part of the agricultural economy, falls from trees are common. This study aims to comprehensively analyze the causes and consequences of spinal cord injuries due to falls from trees.

Methods: This retrospective study reviewed cases of spinal cord injury resulting from falls from trees, treated at a tertiary rehabilitation center between March 2020 and November 2023. Data encompassed demographics (age, gender, occupation, education), spinal injury specifics (level, severity), additional injuries, tree fall details (type of tree, height of fall, cause of fall, safety precautions), and treatment details (surgery need, hospital stay duration). The patients who fell from trees were divided into two groups: those who fell from walnut trees and those who fell from other trees, and statistical analyses were performed accordingly.

Results: Among the 49 patients falling from trees, the mean age was 52.3±13.4 years, with 73.5% being male, 32 patients (65.3%) had graduated from primary or secondary school. No safety precautions were taken by any participants. Paraplegia (87.8%) and complete spinal cord injuries (57.1%) were common. Additional injuries occurred in 61.2% of cases. In terms of fall causes, the most common was branch breakage (57.1%), while walnut trees accounted for 44.9% of falls. There was a significant difference in education levels between the group that fell from walnut trees and the group that fell from other trees (p: 0.028). Falls from walnut trees resulted in higher fall heights, complete injury rates, and longer hospital stays (p:0.003, p:0.047, p: 0.010).

Conclusion: This study found that spinal cord injuries from falls often lead to additional injuries, with none of the patients taking safety precautions. This study found that walnut trees were the most common cause of spinal cord injury from falling trees. This study highlights the need for improved safety precautions and educational interventions.

Keywords: Fall from height, spinal cord injury, walnut tree

INTRODUCTION

Spinal cord injury (SCI) is a significant health issue that results in physical, social, and psychological challenges, as well as a loss of neurological function. Traumatic SCI accounts for approximately 5% of all trauma cases.[1] Traumatic SCI is a major cause of morbidity and mortality and leads to a reduction in the productive population because it is more common in young patients. In addition, the prolonged and costly treatment of traumatic SCI places a significant financial burden on healthcare systems.[2] The most common type of traumatic SCI is falling (40.9% worldwide, 39% in Turkiye).[3,4]

As mechanization is not widespread in underdeveloped or developing countries, falls are common among people who travel to trees to collect produce. This rate is lower in developed countries where harvesting is mechanized. The use of safety equipment when collecting products from trees reduces the complications caused by falling from trees.[5] Injuries to the spine, extremities, head, and spinal cord are frequently observed as a result of falls from trees. Walnut trees are an important part of the Turkish economy. As falls from walnut trees are common in Turkiye, studies have been conducted to investigate the demographic characteristics of patients who have fallen from these trees.[6,7] Falls are common due to the slippery structure of the walnut tree, its height, the fragility of the branches, and the dense presence of walnuts

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at the ends of the branches.[5,7] As falls are preventable causes of death and disability, public health strategies should be developed, and groups at risk should be identified. The severity of such injuries depends on the age of the patient, the cause of the fall, the height of the fall and the structure of the ground on which the patient falls.[5]

In our country, spinal cord injuries resulting from falls from trees are common and carry significant economic repercussions, including both lost productivity and healthcare costs. This study aims to analyze the characteristics of patients who have sustained spinal cord injuries due to falls from trees, as well as the causes and consequences of such falls.

METHODS

This retrospective study included 49 patients with SCI due to falls from trees who were treated to the physical therapy and rehabilitation department between March 2020 and November 2023 using the database of Ankara Bilkent City Hospital-Physical Therapy and Rehabilitation Hospital in Turkiye. All procedures performed in this study were in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee of Ankara Bilkent City Hospital (Date: 12.07.2023, Decision No: E2-23-4500).

Assessments

The records of patients admitted to the spinal cord injury rehabilitation service of a tertiary rehabilitation center were retrospectively reviewed. The demographic characteristics of the patients, including age, sex, occupation, and education level were recorded. The level and severity of neurological injury, determined according to the International Standards for neurological classification of spinal cord injury (ISNCSCI) (2019) published by the American Spinal Injury Association (ASIA), were recorded.[8] The characteristics of the fall were documented, including the date of the fall, type of tree, fall height (measured in meters), the reason for the fall (e.g., branch breakage, loss of balance, or slipping), and whether safety precautions were taken prior to the fall. Data on the admission method to the emergency department following the fall, the time taken for emergency admission, additional injuries, and the need for surgical intervention were collected. The duration of hospitalization in the postoperative ward and intensive care units were recorded. Data were obtained from patient notes and supplemented by contacting patients via phone calls to gather any missing information.

Statistical Analysis

All the data were analyzed using the SPSS 25.0 package in a computer environment. Variables are summarized as the frequency "n", percentage "%", arithmetic mean "mean", standard deviation "SD", median, and 1st quartile-3rd quartile (Q1-Q3). Categorical data were compared by Pearson's Chi-square test or Fisher's exact test. The Shapiro-Wilk test was used to evaluate the conformity of continuous data to a normal distribution. Independent two-sample t tests were used to determine the differences between independent groups in the analysis of continuous variables with a normal distribution, and the Mann-Whitney U test was used in the analysis of independent paired groups of continuous variables without a normal distribution. In this study, $p<0.05$ was considered to indicate statistical significance. Effect size values are given as Cramer's V coefficient for the chi-square test, rank biserial correlation for the Mann-Whitney U test, and Cohen's d for the student's t test.

RESULTS

This study included 49 patients with spinal cord injuries caused by falls from trees. Among the patients, 26.5% (n: 13) were female, 73.5% (n: 36) were male, and the mean age was 52.3±13.4 years. The most common characteristics of SCI were paraplegia (87.8%, n: 43) and complete injury (57.1%, n: 28). None of the patients were found to have taken safety precautions before climbing the tree. All patients underwent spine surgery. All patients were taken to hospital by ambulance after their falls. The most common cause of falls was branch breakage (57.1%, n: 28). A total of 61.2% (n: 30) of the patients had additional injuries, and the most common site of injury was the lung (18.4%, n: 9). The descriptive characteristics of the patients are shown in Table 1.

Table 1. Descriptive characteristics of the patients

Age (years)		52.3±13.45
Gender	Female	13 (26.5%)
	Male	36 (73.5%)
Ocuupation	Officer	4 (8.2%)
	Laborer	15 (30.6%)
	Academician	1 (2.0%)
	Farmer	6 (12.2%)
	Not working	14 (28.6%)
	Pensioner	9 (18.4%)
Level of education	Primary-secondary school	32 (65.3%)
	High school-university	17 (34.7%)
SCI characteristics	Tetraplegia	6 (12.2%)
	Paraplegia	43 (87.8%)
	Incomplete	21 (42.9%)
	Complete	28 (57.1%)
Cause of fall	Branch breakage	28 (57.1%)
	Dizziness, loss of balance	12 (24.5%)
	Foot slip	9 (18.4%)
Time to emergency department (min)		53.4 (20.0-150.0)
Additional injury	Yes	30 (61.2%)
	No	19 (38.8%)
Sites of injury	Head	3 (6.1%)
	Lung	9 (18.4%)
	Rib	2 (4.1%)
	Extremities	4 (8.2%)
	Lung+limb	2 (4.1%)
	Lung+cot	4 (8.2%)
	Hip	5 (10.2%)
	Hip+head	1 (2.0%)

The data are presented as the n (%), mean±SD or median (Q1-Q3), SD: Standard deviation

In this study, walnut trees were found to be the most common etiological cause of SCI due to falls from trees (n: 22, 44.9%),

followed by apple trees (n: 5, 10.2%) and plum trees (n: 4, 8.2%) (Figure). For this reason, the analyses were divided into 2 groups: group 1 (falls from walnut trees) and group 2 (falls from other trees).

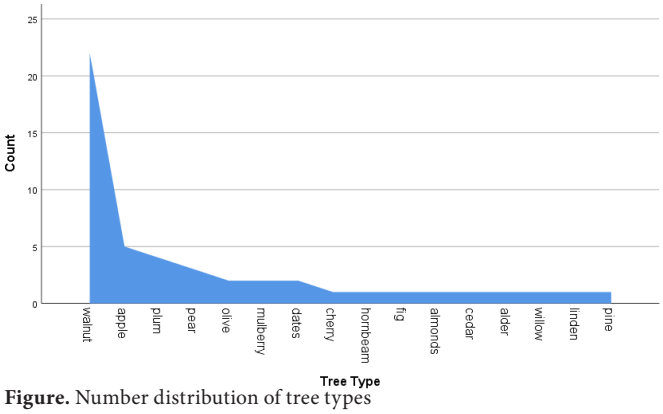

Figure. Number distribution of tree types

There were 5 females and 17 males in group 1 and 8 females and 19 males in group 2. There was no statistically significant difference between the groups in terms of sex (p: 0.580). The percentage of primary and secondary school graduates in group 1 (81.9%) was significantly greater than that in group 2 (51.9%) (p: 0.028, effect size: 0.313). The rate of complete injury in group 1 (72.7%) was significantly greater than that in group 2 (44.4%) (p: 0.047, effect size: 0.284). There was no statistically significant difference in the level of neurological injury between the groups (p: 0.077, effect size: 0.289). The proportion of those who fell from trees in the summer-autumn season was significantly greater in group 1 (100%) than in group 2 (77.8%) (p: 0.027, effect size: 0.337). The fall height of 5.5 (4-7) m was significantly greater in group 1 than in group 2 with 3 (3-5) m (p: 0.003, effect size: 0.483). There was no significant difference in the cause of the fall between the groups (p:0.360, effect size:0.130). There was no statistically significant difference in additional injuries between the groups (p:0.136, effect size:0.213). The length of hospital stay was 30 (13-90) days in group 1 and 14 (7-20) days in group 2, with a statistically significant difference between the groups (p: 0.01, effect size: 0.428) (Table 2).

There was no statistically significant difference between the severity of neurological injury and the height of the fall [(p: 0.089, effect size: 0.426) (p: 0.25, effect size: 0.187)]. There was no statistically significant difference between the severity of neurological injury and the cause of the fall [(p: 0.688, effect size: 0.213) (p: 0.615, effect size: 0.110)]. The proportion of high school and university graduates was 70.6% in the incomplete injuries group and 29.4% in the complete injuries group, with a statistically significant difference between the groups (p: 0.004, effect size: 0.408) (Table 3).

DISCUSSION

This is the first study in Turkiye to analyze the characteristics of patients with SCI with a tree fall etiology. In this study revealed that the patients were mostly middle-aged and male, and the most common SCI characteristics were paraplegia and complete injury. None of the patients took safety precautions before climbing a tree. Additional injuries (most commonly to the lungs) were observed in 61.2% of the patients. The most common type of tree in terms of etiology was walnut, and the most common cause of fall was branch breakage. In the group that fell from walnut trees, the fall height, complete injury rate, and length of hospital stay were longer compared to the group that fell from other trees. It was also found that the educational level of those who fell from walnut trees was lower.

The incidence of SCI due to falls has been gradually increasing in the United States of America over the past 40 years. Data obtained from the National Spinal Cord Injury Database indicate that the percentage of spinal cord injuries

Table 2. Relationships between tree type and sex, education level, level of neurological injury, severity of injury, season, height of fall, and presence of additional injury

		Tree type			
		Group 1 (Walnut tree) n: 22	Group 2 (Other trees) n: 27	p	Effect size
Age[a], mean+SD		52.5±15.1	52.2±12.2	0.940	0.020
Gender[b]	Female	5 (22.7%)	8 (29.6%)	0.580	0.078
	Male	17 (77.3%)	19 (70.4%)		
Level of education[b]	Primary-secondary school	18 (81.8%)	14 (51.9%)	0.028	0.313
	High school-university	4 (18.2%)	13 (48.1%)		
Neurological injury level[c]	Tetraplegia	5 (22.7%)	1 (3.7%)	0.077	0.289
	Paraplegia	17 (77.3%)	26 (26%)		
Injury severity[b]	Complete	16 (72.7%)	12 (44.4%)	0.047	0.284
	Incomplete	6 (27.3%)	15 (55.6%)		
Season[c]	Winter/spring	0 (0%)	6 (22.2%)	0.027	0.337
	Summer/autumn	22 (100%)	21 (77.8%)		
Fall height (m)[d], median (Q1-Q3)		5.5 (4-7)	3 (3-5)	0.003	0.483
Cause of fall	Branch breakage	11 (50%)	17 (63%)	0.360	0.130
	Dizziness-foot slip	11 (50%)	10 (37%)		
Additional injury[b]	Yes	16 (72.7%)	14 (51.9%)	0.136	0.213
	No	6 (27.3%)	13 (48.1%)		
Length of hospitalization[d] (day) median (Q1-Q3)		30 (13-90)	14 (7-20)	0.010	0.428

[a]Student's t test, [b]Pearson's Chi-square test, [c]Fisher's exact test, [d]Mann-Whitney U test, The data are presented as the n (%), mean±SD or median (Q1-Q3), SD: Standard deviation

Table 3. Relationships between neurological injury and the severity of injury and between fall characteristics and education level

		Neurological injury level				Injury severity			
		Paraplegia	Tetraplegia	p	Effect size	Complete	Incomplete	p	Effect size
Fall height (m)		4 (3-5)	6.5 (4-7)	0.089[a]	0.426	4.5 (3-6.5)	3 (3-5)	0.250[a]	0.187
Cause of fall	Branch breakage	24 (85.7%)	4 (14.3%)	0.688[b]	0.213	16 (57.1%)	12 (42.9%)	0.615[c]	0.110
	Dizziness-foot slip	19 (90.5%)	2 (9.5%)			12 (57.1%)	9 (42.9%)		
Level of education	Primary-secondary school	28 (87.5%)	4 (12.5%)	1[b]	0.011	23 (71.9%)	9 (28.1%)	0.004[c]	0.408
	High school-university	15 (88.2%)	2 (11.8%)			5 (29.4%)	12 (70.6%)		

[a]Mann-Whitney U test, [b]Fisher's exact test, [c]Pearson's chi-square test, The data are presented as the n (%), mean±SD or median (Q1-Q3), SD: Standard deviation

(SCI) related to falls was 17% in 1970 and increased to 31% between 2010 and 2013, among all causes of SCI.[9] Falls from trees are common in countries where agriculture is a major source of income. In a study by Nabi et al.[10] in Kashmir of 120 patients who fell from a walnut tree, neurological deficit was reported in 20% of patients, and complete paraplegia was reported in 7% of patients. In a study by Ersoy et al.[6] in Turkiye, 44.4% of 54 patients who fell from a walnut tree had a spinal fracture, and 18.5% had a neurological deficit. In our study, paraplegia was observed in 87.8% and complete injury in 57.1% of patients with SCI caused by falling from a tree.

A study by Chen et al.[11] reported that fall-related SCI was more common in patients over the age of 45. Javadi et al.[12] reported that patients who fell from a walnut tree were most often young men. In our study, SCI due to falls was most frequently observed in middle-aged men (mean age 52.3 years). These findings suggest that the differences in age groups and genders among studies may indicate the need for research and health policies to be shaped according to these demographic characteristics.

Walnut trees play an important role in Turkish agriculture.[6] In 2017, 210 thousand tonnes of walnuts were produced in Turkiye. Turkiye accounts for 5.2% of the world's walnut production.[13] In Turkiye, walnut harvesting is performed by climbing trees, as mechanization is not widespread.[6] Walnut trees are tall (15-30 meters), and the walnuts are at the end of the branches and are at risk of falling due to their slippery surface. When the walnut fruit ripens and falls from the tree, it causes product loss due to damage to the shell. For this reason, farmers prefer quick, economical but risky methods for climbing trees and collecting walnuts. The high selling price of walnuts also encourages pickers to take this risk. In walnut harvesting, the structure of the tree, unpruned branches, carelessness of the pickers, and lack of safety precautions increase the frequency of falls, especially from walnut trees.[5] In this study, the group that fell from walnut trees showed higher fall heights, complete injury rates, and longer hospital stays compared to the group that fell from other trees. These findings reveal that risks associated with the physical characteristics of walnut trees and harvesting methods have a significant impact.

A previous study reported that 47.2% of patients who fell from a walnut tree were farmers and laborers.[5] In our study, the most common occupations among patients who fell from trees were laborers (30.6%, n=15) and individuals not working (28.6%, n=14). Additionally, 65.3% of the respondents completed primary or secondary school, while 34.7% completed high school or university. Furthermore, the rate of primary and secondary education completion was significantly higher in the group that fell from the walnut tree compared to the other group, indicating that those who fell from walnut trees had lower education levels than those who fell from other trees. In this study, the rate of primary and secondary school graduates among patients with complete injuries was significantly higher compared to those with incomplete injuries. These findings suggest that lower education levels may be associated with more severe (complete) spinal cord injuries, potentially due to a lack of awareness or adherence to safety measures during high-risk activities such as walnut harvesting.

In a study by Azizi et al.,[5] the average fall height from a walnut tree was 4 m, and the most common cause of falls was branch breakage. In our study, the fall height was significantly greater in the group that fell from a walnut tree (5.5 m) than in the other group (3 m). While the severity of falls is generally influenced by factors such as the age of the patient, the type of fall, the height of the fall, and the structure of the ground on which the fall occurred.[5] Our study found no significant difference between the severity (paraplegia/tetraplegia) or degree (complete/incomplete) of neurological injury and the height of the fall. This may be attributed to the significant impact of other factors, such as the type of fall and ground structure.

In addition, the most common cause of falls in our study was branch breakage. We believe that this situation is the result of the thin and slippery surface of the branches of walnut trees. In one study, it was reported that pesticides from the leopard moth (*Zeuzera pyrina* L.) accumulated in walnut trees, causing the branches to form a superficially normal, thick but hollow branch. This situation shows that the branches of walnut trees cannot bear the weight of human beings and break easily.[14]

Tabish et al.[15] highlighted that falling from walnut trees is an occupational disease and that safety precautions should be taken before climbing the tree. The fact that not all patients in our study took safety precautions before climbing the tree supports the importance of training in this area. As walnut trees are tall, the construction of 20-30 foot tree stands, the use of nonslip boots and the use of chest and abdominal protectors should be encouraged. Training should be provided in rural areas.

A previous study reported that 94.39% of walnut tree falls occurred in the summer/autumn season.[5] Similarly, our study revealed that 100% of the walnut tree group and 77.8% of the other group fell during the summer/autumn season. These results indicate that safety measures should be prioritised during these peak harvest times to reduce the frequency of tree-related injuries.

A study by Yalçın et al.[16] reported that the use of a trunk and branch shaker machine shortened the walnut harvesting time and increased the harvesting success. In addition, they reported that harvesting by climbing the tree caused damage to the branches and resulted in loss of the following year's crop. We believe that as mechanization increases in our country, spinal cord injuries due to falls from heights will decrease, and hospital costs will decrease accordingly.

The time to the emergency department (min) after a fall was reported to be a minimum of 25 minutes and a maximum of 24 hours in a study by Ersoy et al.[6] and 5.8 hours in a study by Nabi et al.[10] In the current study, this period was observed to be 20-150 minutes (Q1-Q3). This variation in time to the emergency department underscores the importance of timely medical intervention following falls, as delays can potentially impact treatment outcomes and recovery for SCI patients.

Azizi et al.[17] studied 127 patients who fell from a walnut tree and reported that the most common injuries were to the trunk (chest, pelvis, abdomen) (25.9%), lower limbs (20.7%), spine (18.11%), head and face (13.3%), upper limbs (11.8%) and combined injuries (9%). In a study of 115 patients who fell from a walnut tree, Baba et al.[18] reported that the most common additional injury was head trauma (29.4%), and the most common fractures were in the thoracolumbar region (16.5%). In a study by Taçyıldız et al.,[19] SCI was observed in 35.1% of 98 patients who fell from a tree. It was reported that 5.1% of these patients had paraplegia, 27.7% had lung injury, 24.4% had fractures (scapula, tibia, clavicle, pelvis, radius, humerus, calcaneus, fibula, phalanx), and 21.1% had rib fractures. In a study by Ersoy et al.[6] of 54 patients who fell from a walnut tree, the most common injuries were vertebral fractures (44.4%), extremity fractures (41.7%), head and neck injuries (25.9%), and thorax injuries (20.4%), and more than one additional injury was reported in 24% of patients.[6] In our study, 61.2% of the 49 patients with SCI due to falling from a tree had additional injuries. The most common additional injuries were lung (18.4%), hip (10.2%), extremity (8.2%), head (6.1%), rib (4.1%) and combined injuries (14.3%). These findings underscore the prevalence of additional injuries associated with falls from trees and reinforce the need for comprehensive assessment and management strategies for patients with spinal cord injuries.

A study by Azizi et al.[17] reported that the average hospital stay for patients who fell from a walnut tree was between 1 and 22 days. In our study, we found that the duration of hospitalization in the post-operative ward and intensive care units of those who fell from walnut trees was significantly longer (30 days) than that of the other group (14 days). These findings suggest that falls from walnut trees are associated with more severe injuries, leading to extended hospital stays compared to falls from other types of trees.

Limitations

The limitation of our study is that height and weight were not determined. In future studies, height and weight ratios can be determined in the rehabilitation center and their effect on fall-related complications can be investigated. Only patients from a specific area were evaluated, not all patients who fell from trees were evaluated, and the process of patients returning to work was not evaluated.

CONCLUSION

Additional injuries are common in SCI due to falling from a tree. The fact that none of the patients took safety precautions suggests that training on this subject should be provided. In addition, the walnut tree was the tree type with the highest number of falls from trees. Those who fell from walnut trees had a higher rate of complete spinal cord injuries and length of hospitalization, which may indicate a significant impact on health outcomes.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study was carried out with the permission of Ethics Committee of Ankara Bilkent City Hospital (Date: 12.07.2023, Decision No: E2-23-4500).

Informed Consent

Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process

Externally peer-reviewed.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Financial Disclosure

The authors declared that this study has received no financial support.

Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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